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15 TITLE OF THE INVENTION

VOICE OPTIMIZATION IN A NETWORK HAVING VOICE OVER INTERNET
PROTOCOL COMMUNICATION DEVICES

20 CROSS-REFERENCE TO RELATED PATENT APPLICATIONS

U.S. Serial No. 09/220,232, filed December 23, 1998 and entitled
WIRELESS MULTI-SITE NETWORKING USING SIGNALING AND VOICE OVER
INTERNET PROTOCOL, now pending.

25 BACKGROUND OF THE INVENTION

Field of the Invention

30 The invention relates to optimizing voice quality on networks that have voice over Internet Protocol communication devices. The optimization is based on taking and evaluating measurements of network performance pertaining to quality of the network connection.

Discussion of Related Art

The contents of U.S. Serial No. 09/220,232 is incorporated herein by reference.

Support for end-to-end voice calls using the Internet as an alternative to traditional public switched telephone networks (PSTN) is conventional. Unlike the PSTN, which is circuit-switched, the Internet is packet-switched; communication on the Internet is accomplished by transmitting and receiving packets of data.

In addition to data, each packet contains an address to ensure that it is routed correctly. The format of these packets is defined by the Internet Protocol (IP). One type of allowable data is encoded, digitized voice. Thus, voice over IP (VOIP) is voice that is packetized as defined by IP, and communicated over the Internet or some other IP network for telephone-like communication.

Devices such as personal computers (PC) that are VoIP ready, wireless VoIP devices, intelligent phones that are VoIP ready, conferencing units, trunks that are VoIP ready, multi-media devices that are VoIP ready, and plain old telephone system (POTS) telephones connected to VoIP gateways may be VoIP end-points. Examples include Microsoft's NetMeeting, Nortel Networks's soft-client and IP based personal digital assistant (PDA) devices.

These end-points require real-time performance over IP networks. The end points are assumed to be distributed on one or more IP networks. Some devices will be on the same subnet on the same local area network (LAN) segment while others will be on different subnets, some of which could be at the end of a slow wide area network (WAN) connection. A problem arises, however, with respect to voice quality and other quality of service (QoS) parameters in an IP network.

Conventionally, bandwidth is reserved for particular IP end points by marking their packets with a priority level.

However, about 90% of the networks today are not policy managed. With respect to the 10% that are policy managed, there are no solutions to the problems that exist when the bandwidth is insufficient to support a badly configured IP end-point.

5 Conventional software tools are available to help assess the performance of a network by measuring parameters of network performance. Such tools include a Ping tool, a Network trace tool and a packet loss measurement tool. These tools are standard with MICROSOFT WINDOWS product. They run from the
10 command line (found under Start, Run on all WINDOWS operating systems). The commands are 'ping IP_Address' or 'Trace IP_Address'. These tools are available with TCP/IP protocol stacks found under operating systems such as Linux/VxWorks, etc.

5 With the telecommunications networks transitioning from circuit switching to packet switching, phones, trunks and wireless devices are expected to be VoIP capable. Controlling these phones, trunks, and wireless devices to optimize media performance is desired.

20 BRIEF SUMMARY OF THE INVENTION

An aspect of the invention resides in an apparatus and a method of optimizing voice quality on a network having end-point devices, such as voice over Internet Protocol (IP) devices. The invention includes initializing default parameters for the
25 end-point devices with respect to choice of preferred CODEC, number of voice samples per IP packet and jitter buffer size. Further, performance parameters are measured and if warranted by an indication from the performance parameters that the connection to the network is below a desired level of operation, the default
30 parameters are adjusted. The measurements include network bandwidth, number of network hops to the IP end-point devices, round trip delay and packet loss over a time duration. Software tools used to obtain the measurements may include a ping tool, a network trace tool and a packet loss measurement tool. The

adjustment of the default parameters may involve re-negotiating a CODEC connection, re-setting the packet size and/or re-setting the jitter buffer size.

Preferably, a private branch exchange is on the network. A register is configured to register the end-point VOIP devices with the private branch exchange (PBX) on the network. In response to the register completing registration of the end-point devices with the PBX, a terminal proxy server may set the default parameters of the registered end-point devices on the basis of measured performance parameters. Thereafter, the default parameters are adjusted as necessary to better optimize the connection on the basis of changes to the performance parameters as measured by the software tools.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

For a better understanding of the present invention, reference is made to the following description and accompanying drawing, while the scope of the invention is set forth in the appended claims.

Fig. 1 shows a flow chart representing a condition of the invention at initialization time.

Fig. 2 shows a flow chart representing a three-phase approach in accordance with the invention.

Fig. 3 shows a schematic representation of IP telephony in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION

Before discussing the figures 1-3, a brief discussion about various terms used in this patent application may be helpful in better understanding the invention.

Bandwidth usually refers to maximum available bit rate for a specific application. In a specific embodiment, synchronous, interactive, and real-time applications, which are bandwidth-sensitive, can require minimum bandwidth guarantees, and can require sustained and burst-scale bit-rates. On the other

hand, network administrators may want to limit bandwidth taken by non-productive traffic. However, even though bandwidth may be allocated for specified applications, it does not mean that these applications may be using that bandwidth.

5 Jitter generally refers to variation in delay (e.g., the delay is not constant for all packets of a given flow) for a particular application. Real-time applications have maximum jitter limits. Applications such as real-audio and video do some advanced buffering in an attempt to overcome variation in packet
10 delays--the amount of buffering is determined by the expected jitter.

A jitter buffer is a variable length buffer that stores voice packets. The size of the jitter buffer may be dependent upon the variation in the end-to-end packet delay in the network and can be dynamically adjusted based upon, for example, this
5 packet delay variation.

Latency generally refers to the delay experienced by a packet from the source to destination. Latency requirements are typically specified as mean-delay and worst case delay in some cases. Delay is a result of propagation delay, due to physical
10 medium and queuing at intermediate nodes such as routers, gateways, servers, etc. A certain portion of the delay can be controlled by changing the way in which the queues are serviced at the intermediate nodes, and by controlling congestion at
25 bottleneck points. Some examples of delay measurements are packet round-trip delay and connection response time.

A Ping tool includes a routine that sends a packet onto the network and obtains a value of the average delay encountered by that packet in reaching the destination and returning.

30 A network trace tool includes a routine that captures and records events and states that occur while the network is operating. Events in a trace chronology may be paired, forming event-pairs. Examples of event-pairs include the start and end times.

A packet loss measurement tool measures the rate of packet loss over a period of time. Packet loss is a rate of loss in a packet or a portion of packets that is generally caused by noise or failure of network elements (e.g., routers, servers) to forward or deliver packets. Packet loss is usually an indication of severe congestion, overload of an element, or element failure (e.g., if a server is down). Even if the packet was not dropped but just delayed, protocols and applications may assume it was lost. Packet loss can cause application timeouts, loss of quality or delay due to retransmitted packets. Indirect results of packet loss may also be measured (e.g., connection retries or data retransmits).

The default parameters of VoIP end-point devices need to be initialized (Fig. 1) and adjusted later as necessary (Fig. 2). Fig. 3 illustrates an example of VoIP end-point devices on a LAN. These devices include a wired VoIP Client (Set B), a wired soft VoIP Client (Set C) and Wireless VoIP CLIENTS (SETS D & E). These identified end-point devices are for illustration purposes only, there can be more or less end-point devices of different types and additional LANs and additional subnets, etc.

The LAN is connected to a WAN via a call server, terminal proxy server and router in a conventional manner. A wired VoIP Client (Set A) is in communication with one or more of the VoIP devices of the LAN via the WAN. The parameters that may be optimized include CODEC selection, packet size (that is, the number of frames per packet), desired latency, packet loss, available bandwidth, number of router hops, and jitter buffer size.

When a VoIP end-point device registers with an IP PBX, the IP PBX may perform a number of tests to determine the optimum configuration for that end-point. It can measure network bandwidth, the number of network hops (if any) to the end point, the round trip delay and/or the packet loss over a short period of time. These tests can easily be done using a ping tool, a

network trace tool and/or a packet loss measurement tool. After initialization, one or more of these tools can be used on regular periods to determine network performance. During active communications, a call re-establishment can be initiated
5 (manually or automatically) to re-apply these parameters.

Turning to Fig. 1, at the time of initialization, the VoIP end-point device registers with the PBX. In response to the registration, a terminal proxy server uses a protocol to instruct the end-point device to use a CODEC of a particular type, a
10 jitter buffer of a particular size, a frame size of so many voice samples, etc. That is, the terminal proxy server sets the default settings for that VoIP end-point device. When the VoIP end-point device attempts to make a call, the subnet addresses of different IP sets are compared.

If the comparison shows that the subnet addresses differ, then the default is set using G729A as the preferred CODEC type for both IP end-point devices, although other CODECS could be chosen as the default CODEC. Otherwise, if the
5 comparison shows that the subnet addresses are the same, then the default is set using G711 as the preferred CODEC type for both IP sets, although other CODECS could be chosen as the default CODEC.

In addition, software tools are used to measure network performance parameters (e.g., jitter, available bandwidth, delay, packet loss, latency, etc). In obtaining such measurements, a
25 ping tool, a network trace tool and/or a packet loss measurement tool may be used to obtain the necessary information for selection of the default settings.

The Ping tool measures latency and bandwidth of the network between IP end-point devices and/or between end-point
30 devices and the PBX. It may do so by measuring the round trip delay between an IP end-point device and a test point. Bandwidth is measured by measuring the throughput per second of a communication link. In cases where a voice path is directly between two IP end-point devices and not through an intermediary

gateway, the test point requests the IP end-point devices to make the measurement on its behalf with respect to latency and bandwidth between the two IP end-point devices that are connected together. The test results become known to the terminal proxy
5 server, which makes the decisions on these parameters on behalf of the IP end-point devices.

If the latency is low and the bandwidth is high, Table 2 is used to select a small number (about 1-4 frames by example only) of voice frames per packet. If the latency is high and the
10 bandwidth is low, Table 1 is used to select a larger number (about 7-10 frames by example only) of voice frames per packet for optimum efficiency.

If the bandwidth is low, such as at 64 kbs, a CODEC with a high compression ratio should be used (as exemplified by G723.1) and the latency will always increase as a consequence.
5 In general, the less bandwidth, the worse the latency will likely be. On the other hand, if the bandwidth is high, the latency could also be high if the CODEC selection, packet size and jitter buffer size is chosen poorly. By recognizing these conditions, however, appropriate changes may be made to these parameters to
20 optimize latency and voice quality.

If there is spare bandwidth, then network efficiency becomes less of an issue. As a result, stuffing a small number, such as less than three, frames per packet produces less
25 delay/latency and yields better voice quality.

The Network trace tool is used to determine the number of Router Hops between IP end-point devices and/or between the end-point devices and the PBX. If the number of hops is small (1-2 for example) and the bandwidth is high, a small number of
30 frames per packet is used from Table 2 for G711. Otherwise, if the number of hops is large and the bandwidth is small, a large number of frames per packet is selected from Table 1 for G729A.

Fig. 2 illustrates a three-phase approach to optimize a VoIP connection, namely, initializing, network performance

monitoring and dynamically intervening or correcting. The initializing phase has been discussed in detail with respect to Fig. 1 and involves optimizing the configuration of the end point devices. The end point is a frame of reference and can be
5 regarded as either the terminal or the gateway.

Network performance monitoring involves periodically performing (e.g., every few minutes, or other time intervals), a maintenance task that measures the network performance. The maintenance task may involve the use of the Ping tool, the
10 Network trace tool and/or the data packet loss measurement tool. If the network is found to have changed significantly as compared to its condition at the time of initialization, the steps mentioned for Initialization with respect to Fig. 1 may be repeated to re-optimize the network. This could be done
5 automatically or at the request of an end-point device.

The default parameters for the end-point devices should be changed where the measured performance parameters signify that connection to the network is below a desired level of operation. If the latency exceeds 200 milliseconds, for instance, changes
10 should be made to the default parameters. For instance, changing the default parameters for the packet size and CODEC type will help. If the bandwidth is below a threshold level of 128 kbs, the default parameters for the preferred CODEC type needs to be changed. If the packet loss is more than 5%, the default
25 parameters should be changed to a low number of voice samples per frame.

The terminal proxy server and the end-point devices make the necessary measurements with the software tools and report the findings back to the terminal proxy server, which uses
30 conventional protocol to instruct the end-point devices to make the appropriate changes in their default parameter settings. Conventional programming is used to implement the instructions from the terminal proxy server.

The next phase involves dynamic intervention or

correction when the end point devices are active on a session. For example, during an active session, when two end-point devices are in voice communication, corrective measures may need to be taken to improve voice quality. Using intelligence in the IP sets, an indication of the voice quality is reported to a centralized terminal proxy server (see Fig. 3).

If the voice quality at either end-point device has degraded below a set threshold value, then the steps mentioned in connection with Fig. 1 at the time of initialization may be automatically implemented. Such degradation signifies that conditions of the network may have changed significantly as compared to the time of initialization. As the voice channel is re-optimizing, a slight interruption may occur in the voice path. The voice paths may be muted by the end points while this transition is taking place. This would make the transition seamless from an end user perspective. Preferably, the user is prompted to acknowledge that such re-optimization action is to be taken, although such prompting is not required.

At the time of initialization, an IP-PBX may be used that could set certain parameters for each device. The parameters are the preferred CODEC, the number of Voice Samples per IP packet, and the jitter buffer size. For VoIP end-point devices that are installed on the same subnet, the IP-PBX may set the parameters the same as follows. The CODEC selection is G711, the number of voice samples that would be sent with each packet is less than five (and thus small, yielding approximately 50% overhead in the TCP/IP frame), and the jitter buffer selected would be very small or none.

This three-phase approach will give the best audio quality with the lowest amount of latency and will use the minimum amount of digital signal processor (DSP) resources. This approach, however, does not ensure a good connection, because it only optimizes the available connection. This approach works well if there is sufficient bandwidth on the local subnet and if the

packet loss is small (this is very probable in this scenario).

For devices on a different Subnet, the IP-PBX may perform a number of tests before defaulting the system with the above parameters. However, to save processing time and power, it could default the system to the above parameters and then perform the tests to adjust the default settings as necessary based on results from the tests.

By pinging the end-points with data, it is possible to measure the throughput, latency and packet loss of the network connection. It is likely that a G729A CODEC, a much larger packet size (e.g., 20 voice sample) and a sizable jitter buffer to allow for out of order packets would be selected.

By continually monitoring the network it is possible to dynamically change the default parameters associated with a VoIP end point so that when a new call is started or received the network connection is optimized.

If a network is experiencing performance issues during a VoIP call, the IP-PBX could either automatically re-negotiate the CODEC connection and re-set the parameters for packet size and/or jitter buffer. The option to perform such dynamic intervention during media transmission could also be provided to the user with a manual interface to start this activity (e.g., similar to the "scan" button on a cordless phone).

Since the bandwidth of the spectrum is much more limited for wireless devices than for that of a wired LAN, the default parameters could be set based on whether the WLAN was a direct sequence spread spectrum (DSSS) (such as 11 mbs) or a frequency hopping (FH) spread spectrum (such as 2 mbs) or other type of spread spectrum. DSSS and FH spread spectrum are two types of modulation techniques for use in wireless communication systems. Depending upon system requirements, each modulation has its set of advantages and disadvantages. In a messaging environment, frequency hopping is more attractive than direct sequence because it requires no power control at a portable

